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THE NEW WATER PUMPING AND PURIFICATION WORKS AT DEFIANCE, OHIO[1]

By Nicholas S. Hill, Jr.[2]

The water supply of Defiance, Ohio, has been taken up to the present time from the Maumee River and delivered without treatment to the consumers. It is not a satisfactory supply without treatment, and as a result there are many shallow private wells used in the city. The works were bought from a private company for $125,000 a few years ago and about $28,000 has since been spent on them. It was realized by the city officials that they must be improved and last year the author was retained to plan these improvements, upon which construction was recently started. The general problem of the supply and the unusual features of the works will be briefly described in this paper.

The estimate of the amount of water to be provided was unusual in that the population of the city remained stationary from 1890 to 1910. It has recently begun to increase, however, and all indications are to the effect that it is about 8500 to 9000 and growing at the rate of about 3 per cent annually, which is the average rate of similar Ohio towns. In addition to this normal increase, about 3000 persons will be brought to the city by the development of an industrial establishment.

At the present time the industrial and commercial use of water in the city is about 21 gallons per capita and the domestic and public use and waste is about 154 gallons. As there are but 1200 services in the city, corresponding to a population of not over 6000, the gross consumption per consumer is about 243 gallons per day. It is not safe to assume that meters will be set on all services immediately, but in view of the high cost of purified water it seems reasonable to expect that steps will be taken at an early date to cut down leaks in the distribution system and check all excessive waste, and that metering will be carried on with sufficient rapidity to keep the consumption within reasonable limits. On these assumptions, with the works furnishing a clear and wholesome supply so that nine-tenths of the population will be consumers, it is reasonable to expect that a supply of 2,000,000 gallons a day will answer all legitimate needs of the city until it attains a population of 16,000, which will apparently be reached about 1932. The initial plant has accordingly been designed to furnish that quantity of water, but provision has been made for future additions to the initial installation without any alteration in the latter. In view of the high cost of construction and the fact that a large reduction in the present waste of water can be made by the city officials, the provision of any greater capacity at this time seemed unwarranted. If meters are not introduced and the future consumption continues at the present high rate, a 3,000,000-gallon plant should be built now, but as the difference in cost between plants of 2,000,000 and 3,000,000 gallons will pay for universal metering, the smaller plant is plainly preferable.

The present maximum hourly rate of consumption is about 3,500,000 gallons daily. In a city like Defiance provision must also be made for ten simultaneous fire streams, equivalent to 3,600,000 gallons per day while they are playing. The maximum hourly demand was accordingly fixed at the rate of 7,000,000 gallons per day. To meet this demand without providing excessive filtration capacity, a clear water basin holding 450,000 gallons was planned. This will supply ten fire streams for three hours and also water for industrial, commercial and domestic uses at the rate of 2,400,000 gallons per day, 60 per cent in excess of the present average daily consumption.

These considerations led to the selection of two 2,500,000-gallon pumps, one a reserve, for the low-lift pumping from the river to the purification plant, through which the water passes by gravity to the clear-water basin. A pump of this capacity will not only furnish all the water needed for the operation of the plant at the uniform rate chosen but also a surplus of about half a million gallons per day for occasional use in removing sludge from the sedimentation basins and other operating requirements. One of these pumps will be electrically driven and the other, the reserve pump, will be driven by a gasoline engine. The high-lift pumps comprise two 3,000,000-gallon electrically-driven units and a 4,000,000-gallon unit driven by a gasoline engine, the three pumps permitting operating combinations which will meet all demands for water. These pumps will all be installed in the old pumping station, and the old intake and wet well will be used. The station will be somewhat remodeled, however, in order to afford safety against inundation during high floods.

The purification plant is being built to clarify and soften the water as well as to render it safe bacteriologically. Its main features are shown in figure 1. The average turbidity of the water is about 200 but at times it rises to 4000. The color averages 40. The total hardness averages 230 and sometimes rises to 350. The average alkalinity is 170 and the average incrustants 60; the calcium hardness averages 172 and the magnesium hardness 58. The average bacterial count at 37°C. is 400 per cubic centimeter but the count runs up to several thousand on occasions. It was neces-

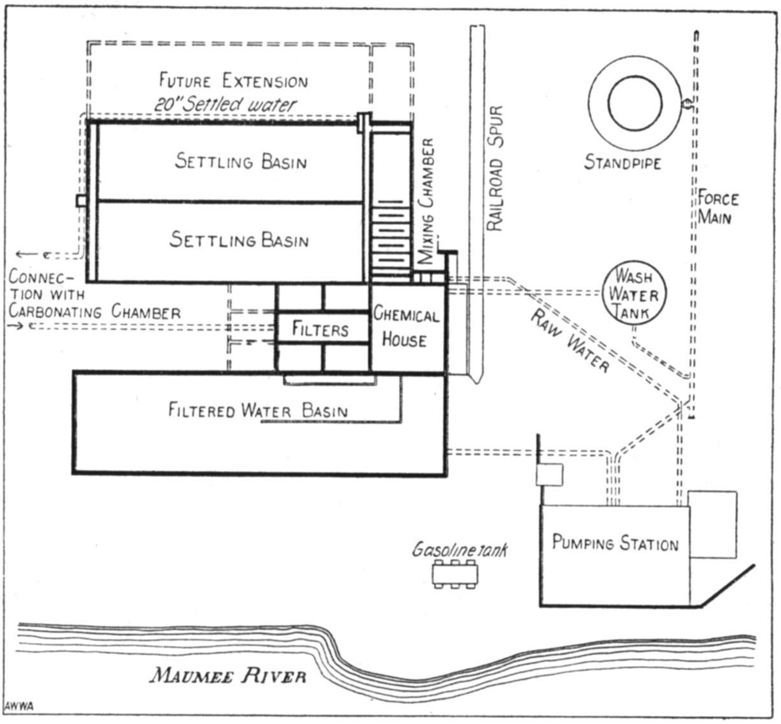

Fig. 1. Arrangement of Defiance Pumping and Purification Plants

sary to design a plant with marked operating flexibility in order to provide for these fluctuations in the quality of the water and to enable the operator to develop the best procedure for each stage of the treatment.

The softening of the water is particularly desirable in the case of a city which is experiencing a decided industrial development. The cost of hard water to power plant operators and the troubles attending its use as boiler feed are drawbacks to any city supplying such water and endeavoring to secure new manufacturing enterprises. Even in a domestic way a water like that of the Maumee River, which requires one pound of soap to soften each 25 gallons of water, is a costly thing. If it is assumed that 5 gallons of water per capita are used daily with soap in Defiance, about 1700 pounds of soap are needed each day. If the hardness of the water is reduced so that one pound of soap will soften 53 gallons of water, about 900 pounds of soap will be saved daily. If this soap is worth 16 cents a pound the saving will amount to $144 a day, which is more than the estimated total daily cost of pumping, purifying and softening the water. In addition there will be a large but indefinite saving due to the reduction of scaling in water-backs in kitchen stoves and the stopping of faucets and to the decreased injury to clothing during washing.

Water is discharged from the low-lift pumps through a float-controlled valve into a weir chamber, figure 2, the entrance to which is guarded by two vertical baffles in order to still the water in the chamber. The water leaves the chamber through Sutro weirs. This type of weir is so shaped that the height of water in the weir chamber will be directly proportional to the quantity passing through the plant; in other words, the rise and fall of the water in the chamber will be in proportion to the rate of filtration. Pipes will run from this weir chamber to the stilling chamber of each of the four dry chemical feed machines, and floats in these stilling chambers will regulate the rate of application of the chemicals to the rise and fall of the water in the weir chamber. A device will be installed to make automatically a record of the flow through the weirs.

The water will fall from the Sutro weirs into the first compartment of the mixing chamber, figure 2. Each compartment is 15 by 5⅓ feet in plan, with a vertical baffle in its center. The water will pass from one compartment to another through an orifice plate having a 15-inch diameter hole, in each division wall, and the vertical baffle walls are provided to prevent any direct currents from one orifice to another. The chemicals will be delivered through rubber hose laid in a vitrified conduit under the roof of the mixing chamber, as shown in two of the cross-sections in figure 2. The rubber hose has the advantages of being flexible, easily cleaned if it becomes clogged, and easily repaired or replaced.

The chemical house, figure 3, has two floors, the lower for receiving chemicals from a spur track running alongside the building, as shown in figure 1, and for pulverizing and storing the lump chemicals, and the upper floor for use as a laboratory, for the chemical feeding and chlorinating apparatus, and storage for a day's supply of chemicals. The two floors are connected by an elevator and have trolley tracks for handling materials easily and quickly. The upper floor is on a level with the top of the mixing chamber and sedimentation basins so that the chemical feeding and mixing can be observed easily. The operator can also pass from this floor through a doorway to the operating floor of the filter plant immediately adjacent to the chemical house, and the lower floor of the house is connected by a doorway with the pipe gallery of the filter house.

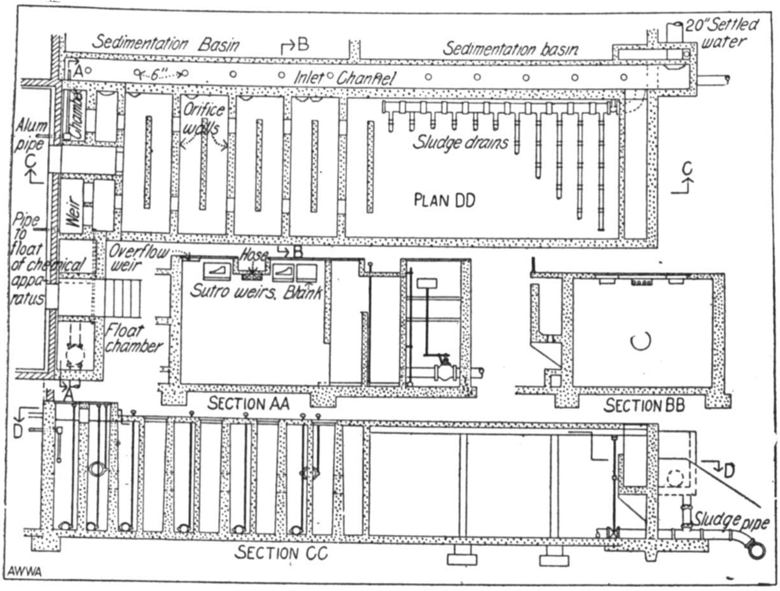

FIG. 2. WEIR AND MIXING CHAMBERS

Outside stairways are provided so that laborers can pass to different parts of the plant without going through the chemical house.

The plant is designed for using either sulphate of alumina or lime and copperas, or both, for purification. Experience in treating similar water at Toledo has shown that at certain times sulphate of alumina is more efficient than lime and copperas and at other times the reverse is true. For softening the water, provision is made for using lime and soda. Each chemical feed machine will be capable of feeding 6 to 120 pounds of ground alum, copperas or soda ash per hour, or 22.5 to 450 pounds of ground quicklime or hydrated lime. The machines will deliver the dry chemicals to ejectors, which will deliver them in turn through 2-inch rubber hose to the mixing chamber, where they can be applied to the water at several points, and alum can also be delivered through a 2-inch lead pipe to the carbonating chamber.

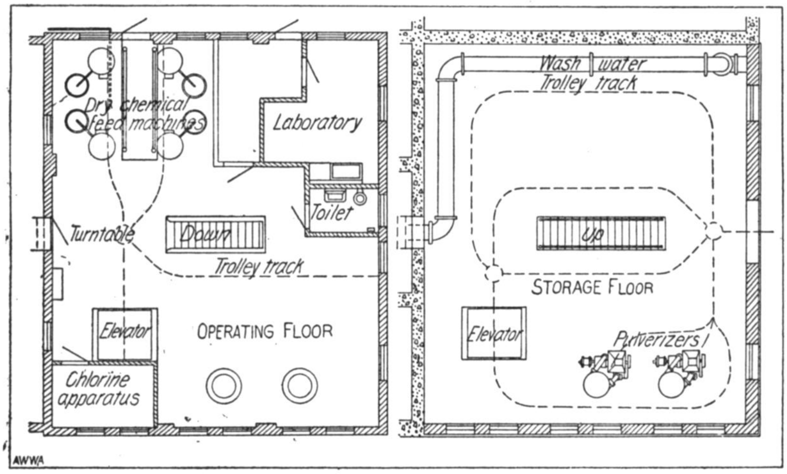

Fig. 3. Floor Plans of Chemical House

After the chemicals have been mixed with the water in the baffled compartments of the first half of the mixing chamber, through which the water will pass in about 30 minutes, the water will enter the large compartment forming the other half of the mixing chamber. The detention period in this compartment will be about 30 minutes, which experiments conducted in the author's laboratory show to be adequate for the necessary chemical reactions to take place to produce a satisfactory floc. Attention is called particularly to the method of removing sludge from this basin, which is used in other parts of the plant for the same purpose. A 12-inch vitrified sewer pipe runs along one wall and 4-inch vitrified pipe branches run from it at right angles. The spigot of each length of pipe is cemented in a sheet-iron cylindrical sleeve and this sleeve is cemented in the bell of the adjoining length of pipe. There is a 1-inch hole in the top of each sleeve as it lies in place on the floor, and through this hole the sludge can be drained off by gravity whenever necessary into a sewer discharging into the river. This system makes it possible to remove sludge without interfering with the operation of the chamber, except at long intervals.

The water will pass over a weir at the end of the mixing chamber into an outlet trough which will deliver it at one end to the inlet trough supplying the two sedimentation basins. This inlet channel, figure 2, discharges water downward through six 6-inch openings into the inlet end of each basin. This method of introducing the water into the basin a short distance above the floor leaves but a short depth for the greater part of the floc to fall, in comparison with the full depth of water through which the floc must settle when the water enters a basin over a weir at the surface. Each basin is 112 feet long, 31 feet wide and 10 feet deep and has a system of sludge drains similar to those in the mixing chamber.

The water is to be softened as well as filtered and chlorinated and a 6-hour detention period has been provided. The water will be drawn from the sedimentation chambers over a weir into an outlet trough, which will deliver it to the main to the carbonating chamber.

One of the greatest difficulties in operating plants for softening and filtering water is that after softening there is usually an excess of lime hydrate in the water, making the latter caustic. The lime collects on the grains of sand in the filters, in the mains and meters and in the house plumbing. In order to neutralize this causticity, a system used at Owensboro, Ky., will be employed. Coke will be burned in a retort in the chemical room and the CO_2 produced by the combustion will be forced through a 2-inch fiber pipe by a blower to the carbonating chamber, figure 4. Here the gas will be delivered to a grid in the bottom of the chamber and allowed to pass up through the water. If the CO_2 is mingled thoroughly with the water and allowed sufficient time to react with the calcium hydrate, the latter will be changed into soluble calcium acid carbonate and the troubles from causticity will be avoided. Generally an attempt is made to rid the water of causticity by allowing it to remain quiescent for 8 to 12 hours in very large settling basins, but the process is not very satisfactory and is more expensive in total cost than treatment with carbon dioxide gas.

The CO_2 grid is composed of concrete troughs which are covered with filtros plates to act as diffusers. The sludge is drawn off through drains with perforated sleeves at the joints, as in the mixing and settling basins. The water enters the carbonating chamber through a submerged orifice at one end and provision is made for adding alum here if desired. The water flows under and over wooden baffles to a weir at the other end, where alum can also be added if desired, and passes over this weir to a 20-inch main to the filters.

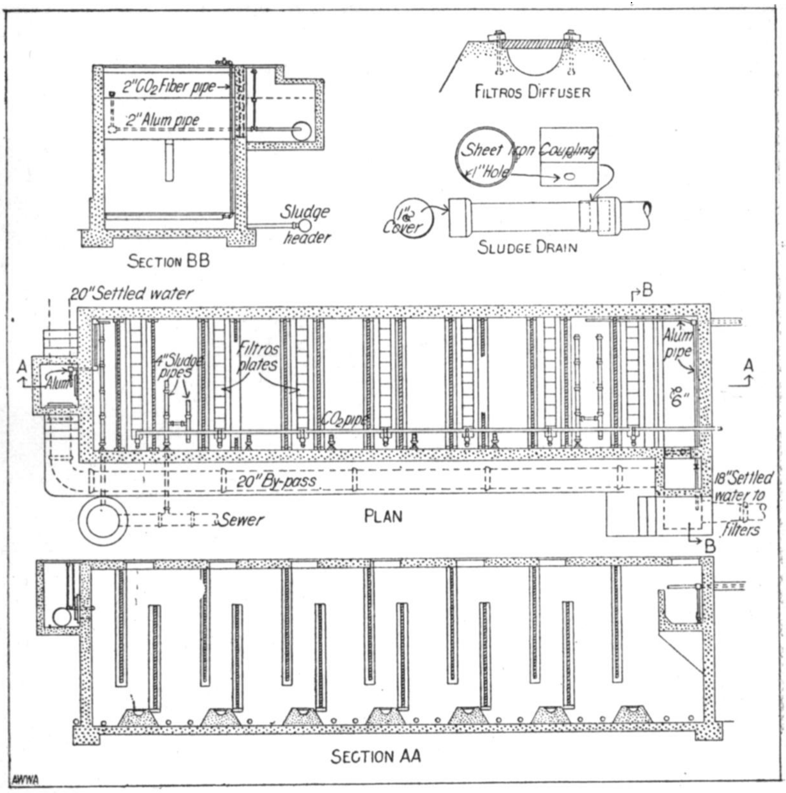

FIG. 4. CARBONATING CHAMBER

Each of the four filters is 18 feet long, and 10 feet 9 inches wide in the clear. The strainer system is made up of 2-inch galvanized wrought iron pipe laid on 6-inch centers and perforated at the bottom, as is the 14-inch cast iron header, with $\frac{9}{32}$-inch holes 6 inches apart. The filter bed will consist of 18 inches of gravel graded upward from coarse to fine, and 30 inches of sand, the depth of the filter bed above the pipes being 42 inches. The effective head is 12½ feet. The filters will be manually operated, as the author's experience shows that this system gives satisfactory results in small plants. The arrangement of the filter piping, figures 5 and 6, is one which has proved satisfactory in other small plants and is characterized by the small number of bends employed. The filtered water is discharged through rate controllers into reinforced concrete conduits which deliver it to the filtered water basin.

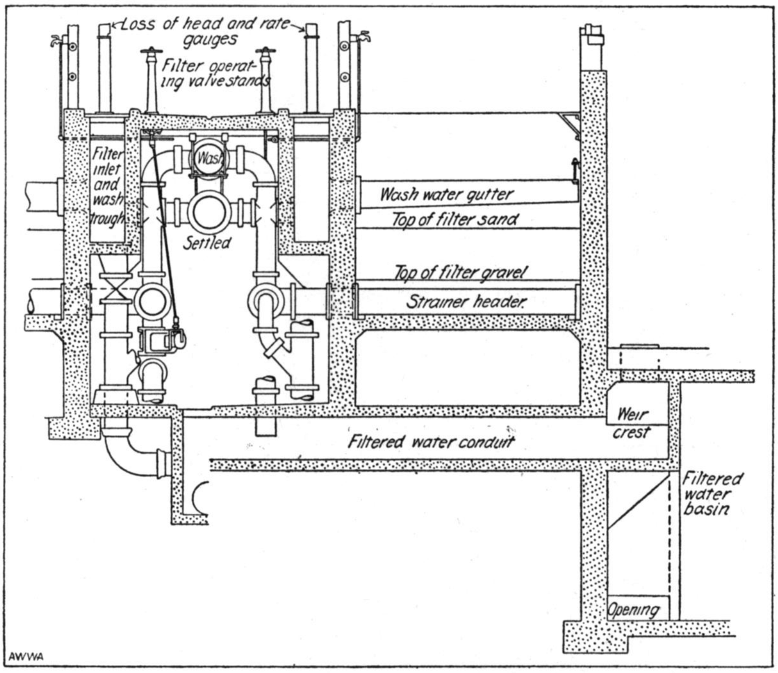

Fig. 5. Transverse Section of Filter Piping

Wash water will be supplied from an elevated tank holding 50,000 gallons raised 50 feet above the ground. This tank will be supplied from the force main to the city. In order that a sudden demand for a large quantity of wash water may not affect the discharge through the force main, a 2-inch pipe will be used to feed the tank. The latter holds enough water to meet all operating requirements at the filters at any washing and will be slowly filled between washings. Provision was made in the plans for the use of 5 per cent of wash water, with a maximum rise of 24 inches per minute or 15 gallons per square foot per minute.

The filtered water basin is 150 feet long, 40 feet wide and 10 feet deep. Water from the filters first enters an inlet chamber along part of one side and then passes over a weir at the end of this inlet chamber into a drop chamber 3 feet square, in which the chlorine diffuser will be submerged. From the bottom of this chamber the water passes out into the clear water basin through the opening shown in figure 5, a vertical baffle being provided in front of the opening to insure good diffusion of the chlorine as well as constant submergence of the gas diffuser. The basin has a tile partition arranged as shown in figure 1, which will cause the water to take a long course before it reaches the suction inlet of the high-pressure pumps. The clear water basin is well ventilated, as experience shows that ventilation of covered basins containing chlorinated water is helpful in removing any odor or taste in the water due to the chlorination process.

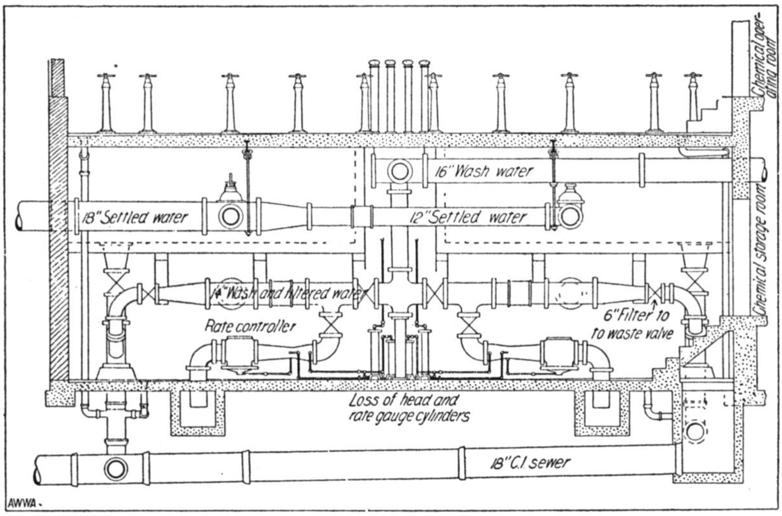

FIG. 6. LONGITUDINAL SECTION OF FILTER PIPING

One of the most interesting features of this plant has been the history of its financial aspect. The author's firm was engaged to design the works in May, 1919. A preliminary report was prepared as rapidly as possible so that the long period of time required in Ohio to finance such public works might be terminated early. By July, 1919, the works were planned and the estimates, based on the prices ruling at that time, amounted to $160,000. A bond issue of $180,000 was authorized to provide this sum and cover the cost of any extras and contingent expenses. Owing mainly to the peculiar laws of Ohio regarding public works financing by bonds, the work was not advertised until February 1920, when the best bid was about $230,000, an increase of 43 per cent over the estimate, which is not surprising in view of the quite general increase of 25 to 50 per cent in the cost of the different items entering into the expense of such structures. The bids were so high that the work was readvertised, and on April 12, 1920, new bids were opened, the lowest being $244,000.

Under the Ohio statutes no municipality can make a contract for construction until the director of public works receives a certified statement from the city auditor that funds are available to pay for it. The maximum amount available for construction from the bond issue was $174,000, so a contract amounting to $137,000 was let to the lowest responsible bidder for the section of the plant comprising all the buildings and structures. It was very desirable to contract at the same time for the piping and filter equipment, in order that their installation might go on while the first contract was being executed. The lowest bids on these two parts of the work amounted to $183,000, and the contracts could not be placed without further funds. At the time, the city had a borrowing capacity of $55,000, without going to the voters, so it was decided to make a temporary loan of $10,000, and to issue at once $55,000 of additional bonds. The low bidders for the standpipe and for the plumbing and heating agreed to go ahead with the work on the understanding that in August, when the proceeds of the additional bonds are available, signed contracts will be given to them. New bids for pumps and electrical apparatus, and their installation, will be requested in August.

These facts are mentioned as showing the difficulties inherent in financing public works in times of great uncertainty regarding the actual costs of outdoor construction, materials and machinery.